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Federal Communications Commission
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November 14, 1996

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Mr. William F. Caton
Secretary
Federal Communications Commission
Room 222
1919 M Street, N.W.
Washington, D.C. 20554

Ex Parte Presentation
ET Docket No. 96-8
ET Docket No. 96-102

Dear Mr. Caton:

On November 8, 1996, an ex parte presentation was made to Commission personnel in the two non-restricted matters referenced above. During that presentation, Commission personnel requested that additional information be submitted.

Accordingly, pursuant to Commission Rule 1.1206(a), a total of four copies of the presentation and the additional information requested (two copies for each docket) are enclosed.

Please contact the undersigned with any questions regarding this matter.

Very truly yours,

Keith A. Barritt

Keith A. Barritt

Enclosures
cc: Bruce Franca, Deputy Chief, Office of Engineering and Technology
Lynn Remly, Chief, Policy and Rules Division
Karen Rackley, Chief, Technical Rules Branch
John Reed, Policy and Rules Division

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EX PARTE PRESENTATION

ET Docket No. 96-102
ET Docket No. 96-8

Presentation to the Federal Communications Commission

Reference to Dockets 96-8 and 96-102

By the International Microwave Power Institute

November 8, 1996

Presented by Wayne Love
IMPI committee chair for spectrum issues
7524 Standish Place
Rockville, MD. 20855
301-251-9070 x 5523

The International Microwave Power Institute (IMPI) is the only organization of ISM device users, equipment builders, researchers, and product users in the United States.

- Founded in 1965.
- Membership numbers about 300 individuals world wide.
- Corporate membership numbers 19
- About 2/3rds of the individual members are in North America.
- IMPI is split into two groups.

ISMI - Industrial, Scientific, Medical, & Instrumentation

MIFTA - Microwave Food Technology & Applications

Spectrum Issues

- ISM equipment has **primary** rights for usage within the ISM bands per FCC regulations.

- Present ISM equipment generally uses the 915 and 2450 MHz. Frequency bands. Some present use at the higher frequency bands to be increasing.

- Most ISM applications are intentional electromagnetic emitters.
  - Therefore the ISM band has a high noise floor and is filled with random frequency signals and spikes , making uses other than ISM processing equipment within the band unwise and unreliable, if not impossible.

- The ISM bands are recognized world wide for ISM use (except 915 MHz.).
  - The ISM bands are virtually the only frequency bands with usage which is defined consistently throughout the world. This is because the characteristic spectrum of ISM equipment makes other uses unwise.

- ISM equipment, products, and processes that benefit virtually every person in the US. include:

Applications	Benefit
Domestic uses Frozen dinners, eggs, baking , popcorn, snacks, reheating leftovers, defrosting food, coffee, vegetables, fish, microwave accessories (bed buddy, glues, bread warmers, hand and foot warmers, etc.).	Yearly popcorn sales is $750 million
Commercial food processing Virtually every restaurant in the US., including every burger sold at McDonalds, Wendys, & Burger King. Vending food applications.	Billions and billions served!
Industrial food processing Frozen food tempering (butter, fish, meat), bacon, meat, croutons, baking (bread and donuts), low fat snacks, poultry, fish, meat patties, pasta, blanching of fruits & vegetables, cereals	Safe and quick food processing.
Medical Oncology, diathermy, blood plasma warming, cornea reshaping, medicine manufacturing.	Life saving & life quality improvements.

Plasma processing Virtually every semiconductor chip made, diamond thin films, and medical equipment sterilization.	Every semiconductor chip! Replaces chemical etching, which results in the elimination of tons of Highly toxic pollutants.
Ultraviolet processing Virtually all compact discs, Coors beer cans. and fiber optic cable made. Linoleum flooring, computer key boards, plastics, printing on paper, plastic, metal, product labels, and glossy paper. Glues ,thin films (plastic films on glass, anti reflection coatings on glass and plastics, automobile head lamps) etc. all use UV curable coatings.	Virtually all CDs & fiber optic cable made use microwave processing to eliminate the tons of organic solvents which otherwise would end up in the atmosphere.
Waste disposal/remediation Soil remediation, safe low level nuclear waste disposal, safe medical infectious waste disposal. chemical sludge dewatering	Efficient elimination of hazardous medical & nuclear waste from the environment.
Chemical processing PVC, plastics, chlorine, foam packaging, chemical digestion, sealing food packages, chemical analysis, solvent extraction.	EPA approved methods dramatically reduce pollution in the chemical industry.
Ceramic processing Technical ceramics, ceramic filters for the casting industry, composite materials,	Allows composite material fabrication for aerospace and industrial applications.
Industrial drying Paper, fibers, inks, glues, wood, thin films, pencils, fabric, carpet, yarns, leathers, pet foods, grain, cotton,	Allows water based processing instead of solvent based, thereby reducing emissions.
Rubber curing Tires and window seals	Only method to make compound rubber window seals.
Asphalt Recycling, curing, repair	LA saved over $ million in 1 year.
Mineral processing Coal, shale, oil, gold, platinum	

- These are some of the many ISM applications presently in use.
- The products and processes touch virtually every American's life each and every day.
- Millions of jobs are created or enhanced by ISM equipment or processes.
- The yearly economic benefit is almost impossible to determine, but is easily hundreds of billions of dollars.
- The benefits to the environment in terms of reduced pollutants are considerable.

Present use of ISM equipment.

The idea that ISM equipment (ovens) are used only 2-5 minutes per day, is simply not accurate.

A typical family of 4 with 1 child over 12,uses their microwave oven 6-12 times per day according to a 1996 IMPI study. This study further shows microwave oven use is increasing.

Use of the 2.45 GHz. spectrum per a recent NTIA study of Denver, Colorado shows widespread use from the city. The 2.45 GHz. spectra does not have the expected emission peaks at the three meal times. Possible reasons include:

Home microwave oven use at other than traditional meal time:

- Baby food
- After school snacks (so called pocket sandwiches and other "mini meals")
- Hot beverages
- Popcorn
- Non food products (bread warmers, hand warmers, therapeutic warmers)

Use of ovens in the office:

- 67% of offices have microwave ovens per IMPI survey.
- Varied break times means ovens are in use many times during the day.

Commercial use:

- Virtually all restaurants have microwave ovens.
- Fast food restaurants including McDonalds (normally 2-10 ovens), Wendys, & Burger King.
- Vending food applications at work places, schools, shopping areas, and airports.

Industrial use:

- Tens of thousands of industrial sites often operating 24 hours per day, 7 days a week.

Future use of ISM equipment.

Medical

- Prostrate, Oncology, and Heart treatment clinics at potentially thousands of sites. Microwave treatments will last an average of 1 hour continuous use. Many sites will be mobile. Microwaves will help diagnostic equipment become faster and more accurate.

Electrodeless lighting

- General commercial, industrial, sports, projection, and residential use lighting. Outdoor and street pole lighting. Even automobile head lights. All have been proposed and shown to be viable with important advantages of traditional light sources.

Industrial

- Plasma semiconductor processing equipment, food processing, UV cured products, waste remediation, medical waste treatment, ceramic sintering, chemical digestion, chemical processing, are some of the ISM applications showing significant growth.
- Further reduction in hazardous waste, solvent use, and chemical pollutants.

Domestic

- New food processes are being developed to reduce time spent on meal preparation. A microwave clothes dryer has shown good performance compared to traditional dryers and is expected to come to market.

Commercial

- Microwave vending machines will soon offer quick, restaurant quality food to consumers in locations too small for staffed restaurants. Schools, hospitals, airports, work places, rest areas, etc. Fast food restaurants are continuing to grow and find microwave ovens especially useful for food warming.

The trend of microwave use is increasing and will continue to increase into the future as applications and processes come into use.

Present ISM equipment spectra.

- Many of the sources in use today are ferroresonant iron core power supplies causing the microwave signals to be pulsed at 60 or 120 Hz. resulting in wide continuously changing frequency spectra (the band will look full if averaged over time).

- Some microwave sources are changing.

Future ISM equipment spectra.

- Continued use of the iron core power supplies for many low cost, wide spread use.

- Other future sources will truly be CW, with a spectrum always on and narrow signal per device. Multiple devices may have offset frequencies filling the band with true CW signals

    - Switch mode power supplies

    - Solid state sources

    - Further development of true CW microwave sources, CW magnetron, Klystron, TWT's, gyrotron, etc.

- Higher power sources results in higher in band peak emission.

Future other ISM bands

Research is ongoing at the higher frequency ISM bands. Equipment and applications examples include:

- Research is being done at 5.8 and 10 GHz. bands.
- A new 24 GHz., 10 kilowatt processing system on the market.
- Material and ceramics processing.
- Plasma processing.
- Material testing.
- Sensors.

Non ISM devices using the ISM bands

- The FCC allowed unlicensed communication devices (wireless LAN's) in the ISM bands in 1989.
- At that time, the FCC was not aware of the amount of ISM equipment , their impact on the US economy, or benefits to citizens.

  The first time evidence of ISM spectrum use was given to the FCC by IMPI was as a result of the 1992 WARC aborted proposal to allow licensed communications use in the ISM bands. We believe that this is the first time the FCC received ISM spectrum use from informed sources.

- The FCC did little to warn these unlicensed communication devices (wireless LAN's) about interference potential - present or future.

  The FCC continues this policy - there is no mention of any ISM bands (even thought they have **primary** usage rights) on their 55 page web site of frequency allocations (DA 96-1704 dated October 16, 1996). This table " can be used when planning business activities that use or are based on wireless communications, yet no mention of the ISM bands.

- The FCC did little or no testing on the impact of ISM devices to these unlicensed communication devices (wireless LAN's).

- The FCC did little or no testing on the impact of these unlicensed communication devices (wireless LAN's) on ISM devices.

- The FCC has encouraged these unlicensed communication devices (wireless LAN's) to spend a great deal of time and resources on the development of equipment that will likely have very limited operational success in the ISM frequency bands to which they do not have primary band rights .

- The FCC has made some preliminary tests on the data transmission rates of unlicensed communication devices (wireless LAN's) in the presence of certain ISM band equipment. The results indicate that a reduction **to**, not of, but to 20% of the data transmission rate with the ISM device operating vs. when it is not operating! With increasing future ISM device use in the band, these data transmission rates will be reduced even further!

- With these preliminary measurements, the FCC has identified an undesirable situation of incompatible sharing of the ISM bands with the primary users and unlicensed communication devices (wireless LAN's).

- It is imperative the FCC continue testing other ISM device interactions with unlicensed communication devices (wireless LAN's).

- It is imperative this information be shared with users of the ISM bands, both primary users and secondary users.

- As has been seen, these unlicensed communication devices (wireless LAN's) have tried to gain a "primary commercial right to the frequency band", to favor their equipment by instructing the users of their equipment to turn off any interfering ISM equipment. By doing so, it is evident the unlicensed communication devices (wireless LAN's) manufacturers foresee a potential for a reduction in data rates.

- The situation of incompatible sharing of the ISM bands will continue to grow as both traditional and new emission spectra ISM and unlicensed communication devices (wireless LAN's) devices gain market entry. This situation will be exacerbated by the FCC's refusal to properly caution unlicensed communication devices (wireless LAN's) about present and future ISM equipment use. This situation is further intensified by the FCC's policy of not requiring immunity standards for these unlicensed communication devices (wireless LAN's). Furthering this situation are the claims of non ISM devices that the "new 2.4 GHz. band is totally uncluttered", and instructions that tell the user to turn off offending ISM devices if there is interference. If these claims and instructions are allowed to continue, the non ISM devices will clearly gain a "primary commercial right to the frequency band", even though they are not designated primary users of the ISM bands.

IMPI recommendations

- As a minimum measure, IMPI urges the FCC to require non ISM devices that operate in ISM bands to meet certain immunity standards (immunity standards are a requirement for all European equipment) and to fully and completely warn non ISM devices and users, unlicensed communication devices (wireless LAN's) in particular, about ISM device usage.

- The International Microwave Power Institute strongly urges the FCC to rethink it's policy of allowing non ISM devices, and unlicensed communication devices (wireless LAN's) in particular in the ISM bands. This undesirable situation of incompatible sharing of the ISM bands with the primary users and unlicensed communication devices (wireless LAN's) has been caused by the FCC's uninformed and incomplete understanding or knowledge of ISM devices in band usage. If allowed to continue unresolved, this situation will grow out of control.

- The user will suffer a severe economic consequence if unlicensed communication devices (wireless LAN's) are allowed to proliferate in any ISM band at the expense of ISM equipment. Today, ISM equipment, products, and processes add hundreds of billions of dollars to our GNP yearly and thousands of jobs. This will increase in the coming years, as new products and processes are realized.

- Existing ISM equipment will operate for 10 - 15 or more years before it is replaced.. It is unwise to allow other than ISM devices in ISM bands. ISM devices have limited number of frequency allocations, which, because of their emission uses the entire band.

- ISM equipment includes medical devices with applications such as blood plasma warming and assisting in quicker diagnostics. Patient treatment uses have been around for many years, and are now increasing with new applications such as prostrate and oncology treatments. If ISM bands are taken away or ISM uses reduced, either by law or by "commercial rights", new beneficial treatments would not be developed. Users would be denied access to the best and safest medical technology available.

- In the end, the user will suffer if this incompatible sharing of the ISM bands by the primary user (ISM devices) and these unlicensed communication devices (wireless LAN's) are not resolved. The user will be confronted with having to choose use in the ISM bands, without proper knowledge of these issues, between ISM devices or non ISM devices, in particular, unlicensed communication devices (wireless LAN's). ISM band devices produce significant benefits and operate in the bands for which they were intended to operate, and the FCC should take the proper steps required to maintain these ISM use in the ISM bands.

NTIA Report 95-323

MEASUREMENTS TO CHARACTERIZE AGGREGATE SIGNAL EMISSIONS IN THE 2400-2500 MHz FREQUENCY RANGE

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U.S. DEPARTMENT OF COMMERCE
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AUGUST 1995

ABSTRACT

This report provides the results of radio spectrum measurements performed to characterize the aggregate signal emissions present in the 2400-2500 MHz industrial, scientific, and medical (ISM) band and adjacent frequency bands. These measurements were performed at locations near Denver, Colorado and Los Angeles, California, and included various frequency domain and time domain tests utilizing omni-directional and directive antennas. The information contained in this report can serve as an aid to designers developing equipments to operate in these frequency bands, as well as authorities seeking to enhance compatibility between ISM devices and other radio services. It should be noted that the frequency bands 2400-2402, 2402-2417, and 2417-2450 MHz have recently been reallocated from Federal use to non-Federal use in response to the requirements of Title IV -- Communications Licensing and Spectrum Allocation Improvement -- of the Omnibus Budget Reconciliation Act of 1993. This further enhances the attractiveness of these frequency bands to equipment manufacturers.

KEY WORDS

Industrial, Scientific and Medical (ISM) Equipment
Microwave Ovens
Aggregate Environment
2300-2600 MHz

ACKNOWLEDGEMENT

This report could not have been completed without the efforts of the National Telecommunications and Information Administration (NTIA) Institute for Telecommunications Sciences (ITS). The ITS Spectrum Use Measurement Group provided data collected with the Radio Spectrum Measurement System. In particular, technical support from John Ewan was essential to the completion of the measurements.

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SECTION 1

INTRODUCTION

BACKGROUND

The National Telecommunications and Information Administration (NTIA) is responsible for managing the Federal Government's use of the radio frequency spectrum. NTIA's responsibilities include establishing policies concerning spectrum assignment, allocation and use, and providing the various departments and agencies with guidance to ensure that their conduct of telecommunications activities is consistent with these policies (NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management). In support of these responsibilities, NTIA has undertaken a number studies to assess spectrum utilization, identify existing and/or potential compatibility problems between systems of various departments and agencies, provide recommendations for resolving any compatibility conflicts, and recommend changes to promote efficient and effective use of the radio spectrum and to improve spectrum management procedures.

Increased demand for spectrum for mobile services has focussed attention within the national and international radio communications community on the frequency bands between one and three gigahertz (GHz). Most of the new technologies will facilitate implementation of radio uses in the terrestrial personal mobile environment, including business and residential areas. Some will involve satellite technology, and manufacturers have considered this frequency range for both uplinks and downlinks. Aside from the identification and allocation of spectrum exclusively for these uses, sharing with existing activities could provide needed spectrum. In order to share spectrum with other radio frequency (RF) uses, the emission characteristics of those uses must be known.

Some service providers and manufacturers have developed new systems near or in the 2400-2500 MHz band, including, for example, a family of products to connect Ethernet local area networks in buildings up to five kilometers apart. The International Telecommunication Union (ITU) designates 2450 ± 50 MHz for use by industrial, scientific, and medical (ISM) equipment.[1] Among the ISM devices operating at that frequency are domestic microwave ovens. The presence of approximately 80 million of these ovens within the United States and over 200 million worldwide, and the investment in terms of industry costs and public outlays, make microwave ovens a major factor in considering options for future radio use of 2400-2500 MHz

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1 *ITU Radio Regulations #752*, International Telecommunication Union, Geneva Switzerland, 1990, p.RR8-105.

and surrounding bands.[2] While some potential radio services may operate in an environment where signals from individual ovens are the primary concern, for other radio services the aggregate microwave oven emissions may have a greater impact. Therefore, characteristics of both individual and aggregate microwave oven emissions must be determined. The potential economic impact of these radio-based technologies makes resolution of issues related to compatibility with microwave ovens essential.

In 1991, the NTIA undertook a study to determine if the Broadcast Satellite (Sound) Service (BSS) could be accommodated between 2300 and 2400 MHz. Measurements performed by the Institute for Telecommunications Sciences (ITS) showed that microwave ovens emit RF energy across a wide spectrum, with high peak levels outside the frequency band designated for ISM use. Subsequent analysis concluded that microwave oven emissions must be taken into account in BSS system design through incorporation of sophisticated signal processing techniques, such as time and frequency interleaving and forward error correction.[3]

The results of this previous NTIA study, and the requirement to ensure that U.S. manufacturers and radio users are adequately considered in the CISPR deliberations, necessitated additional testing and analysis to more accurately determine the level of emissions from individual ovens, the level of aggregate emissions in large metropolitan areas, and the level of emissions outside the 2400-2500 MHz band acceptable to authorized radio services. On this basis, NTIA began a three-part effort to

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2 Other ISM devices include, for example, industrial and commercial grade ovens or heaters for curing and drying of commodities, medical diathermy equipment, and plasma generators. Though many of these systems operate at higher power levels than domestic microwave ovens, their fewer numbers may lower the impact on use of radio systems near the 2400-2500 MHz band. One other potential use of the 2400-2500 MHz band which may become significant in future years involves the development of "RF light bulbs". These devices, incorporating microwaves bombarding gaseous compounds, have been touted as cheaper, safer, and more environmentally friendly than traditional incandescent and fluorescent lights. If they can provide those benefits, and become commercially available, they could become significant sources of concern to radio systems developed for that band.

3 Filippi, C.A., R.L. Hinkle, K.B. Nebbia, B.J. Ramsey, and F.H. Sanders, NTIA Technical Memorandum 92-154, *Accommodation of Broadcast Satellite (Sound) and Mobile Satellite Services in the Band 2300-2450 MHz*, Department of Commerce, National Telecommunications and Information Administration, January 1992, p. 2-3.

1. measure the emissions from a number of new microwave ovens, checking the impact of measurement procedures on the results, and reviewing the utility of measurement procedures in assessing compatibility of oven emissions,

2. measure the aggregate levels of emissions in the 2300-2600 MHz band near large metropolitan areas,

3. determine the level of emissions acceptable to a variety of receiver technologies and formulate appropriate emission limits and methods of measurement

The first of these tasks was completed in early 1994, and the results presented in an NTIA document titled "Radio Spectrum Measurements of Individual Microwave Ovens".[4] This report provides documentation of the data collected in support of the second task -- namely characterization of the aggregate emissions in the 2300-2600 MHz band near large metropolitan areas. Though the majority of the data collected is concentrated within the 2400-2500 MHz band, data were collected which are representative of the surrounding frequencies.

OBJECTIVE

The objective of this task is to provide data to characterize the aggregate signal emissions present in the 2400-2500 MHz ISM band and adjacent frequency bands.

APPROACH

Due to the large number of unanswered questions about potential communications equipments for the 2400-2500 MHz frequency band (e.g. receiver bandwidth, type of receiving antenna, etc.), care was taken to make the tests as generic as possible. Toward this end, six types of data were collected:

A. Frequency Domain Data (versus measurement bandwidth and time of day),
B. Time Waveform Data (20 millisecond sweep, peak detected),
C. Time Waveform Data (20 millisecond sweep, sample detected),
D. Time Waveform Data (60 second sweep, peak detected),
E. Time Waveform Data (60 second sweep, sample detected), and
F. Omni Antenna versus Directional Antenna Tests,

and each is described in detail in the following paragraphs.

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4 Gawthrop, P.E., F.H. Sanders, K.B. Nebbia, and J.J. Sell, NTIA Report 94-303-1 and -2, *Radio Spectrum Measurements of Individual Microwave Ovens*, 2 Volumes, Department of Commerce, National Telecommunications and Information Administration, March 1994.

The Frequency Domain data were intended to provide the system developer with both an indication of band usage as "viewed through" a variety of different receiver bandwidths, and with an insight into the expected diurnal cycle of microwave oven usage. The diurnal cycle data were also utilized to ensure that the time waveform and antenna type data were collected during the periods of peak activity. A complete listing of measurement parameters is contained in Appendix A.

The time waveform tests (B-E) were intended to provide "snapshots" of the type of signals present in the environment, both over the short term, and over a longer "averaged" time interval. Both "worst case" and "average" characterizations were made.

One potential use postulated for this band involves some form of fixed point-to-point microwave service. This type of usage would most probably involve a directional receive (and probably transmit as well) antenna. As a result, tests were performed to determine if the aggregate environment somehow changed when the receive antenna was directive instead of omnidirectional -- for example did the use of a directional antenna allow single ISM transmitters to be discriminated from the aggregate environment?

SECTION 2

RULES AND REGULATIONS

ALLOCATIONS

In the United States the 2400-2500 MHz frequency band is allocated as shown in Table 1.

Table 1: Current United States Frequency Allocations (2400-2500 MHz)

2400-2402		AMATEUR	ISM 2450±50 MHz
2402-2417		AMATEUR	
2417-2450	RADIOLOCATION	AMATEUR	
2450-2483.5		FIXED MOBILE Radiolocation	
2483.5-2500	RADIODETERMINATION-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth)	RADIODETERMINATION-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth)	

Enhancing the attractiveness of this band to equipment manufacturers is the fact that, as required by Title VI -- Communications Licensing and Spectrum Allocation Improvement -- of the Omnibus Budget Reconciliation Act of 1993, the Secretary of Commerce has provided, from the spectrum allocated for Federal use, an aggregate of 235 MHz for allocation by the Federal Communications Commission (FCC) to non-Federal users.[5] Included in these 235 MHz, are 50 MHz from the 2400-2500 MHz band. Specifically, the 2400-2402 MHz band, and the 2402-2417 and 2417-2450 MHz bands have recently been reallocated.

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[5] Hurt G.F., E.A. Cerezo, E.F. Drocella Jr., D.E. Kitzmiller, R.C. Wilson, NTIA Special Publication 95-32, *Spectrum Reallocation Final Report*, Department of Commerce, National Telecommunications and Information Administration, February 1995.

Reallocation of the entire 2400-2450 MHz band provides the FCC with the opportunity to develop a long-term framework and strategy that meets the needs of the amateur service while addressing the requirements of a robust and growing industry of non-licensed devices authorized under FCC Part 15 Rules. Under a mixed use reallocation, the Federal allocation will be reduced to secondary, with the limited remaining Federal presence posing no impact on non-Federal use. This action provides the opportunity to have significant spectrum available for long-term development of non-licensed technologies. Furthermore it provides significant opportunities for innovators and small companies to make contributions to the overall mix of products and services available to the American public.

REGULATIONS AND STANDARDS

In the past, commercial interest in these frequencies has been somewhat tempered by the fact that national and international regulations specify that radio operations in the ISM bands must accept harmful interference that may result from ISM applications. Also, in order to promote ISM use of ISM designated bands, no U.S. or international ISM emission limits have been applied between 2400 and 2500 MHz, or, for that matter, within any of the ISM bands. Thus design of radio equipment to operate in the 2400-2500 MHz band represents a significant challenge.

Outside the ISM bands, emission limits have been established by the FCC, and adopted by the NTIA, to enhance compatibility between microwave ovens and radio services.[6] Though national and international regulations stipulate that ISM equipment must not cause interference outside the ISM bands, enforcement of this regulation for domestic microwave ovens could be both difficult and expensive due to the large number in the hands of the public. Furthermore, if interference to a radio service occurs, it may be caused by an aggregate of microwave oven sources, not a single oven. Therefore, since enforcement of this out-of-band emission regulation may be impractical, radio communications system developers designing equipment for near term implementation must design their equipment to be compatible with the existing RF emissions environment. Implementation of new services and technologies in the long term provides more flexibility since there may be time to update emission standards for microwave ovens. In order for applicable emission limits to continue to facilitate compatibility, spectrum management authorities must periodically review and revise them, consistent with the requirements of future radio systems.

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[6] Emission standards and measurement approaches pertaining to radio interference and electromagnetic compatibility are distinct from those dealing with radiation hazards to people. Within the efforts addressed in this report, NTIA did not measure emissions in a manner applicable to evaluate bioeffects. Radiation hazard aspects are regulated by the Food and Drug Administration under *Title 21, Code of Federal Regulations*, Section 1030.10, "Performance Standards for Microwave and Radio Frequency Emitting Products".

The International Special Committee on Radio Interference (CISPR) Subcommittee B is currently developing international limits for ISM emissions above 1 GHz.[7] Subcommittee discussions have focussed on the emission limits of domestic microwave ovens. The levels emitted by ovens currently in use, the manufacturers ability to limit emissions outside the ISM band (with associated costs), and the needs of radio users constitute the primary factors considered in establishing the limits. The outcome of CISPR discussions will potentially impact U.S. oven manufacturers by establishing the most widely used standard for microwave ovens sold outside the United States. If the FCC chooses to have its standards conform with CISPR, these discussions will impact equipment designed for the U.S. market as well. The lifespan of microwave ovens creates a situation where standards implemented today, and microwave ovens built to those standards, will affect the electromagnetic environment of radio systems to be placed in operation ten or more years in the future.

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[7] CISPR is a body of the International Electrotechnical Committee (IEC) and develops industry standards for preventing radio interference. The American National Standards Institute (ANSI) provides U.S. representation

SECTION 3

MEASUREMENTS AND ANALYSES

PROCEDURES

All data were collected utilizing the NTIA Radio Spectrum Measurement System (RSMS). The RSMS is a mobile, essentially self-contained computer-controlled radio receiving system capable of a wide variety of measurement scenarios over a frequency range of 50 MHz to 22 GHz. These measurements are usually conducted in an automatic mode with computer control of software algorithms that tailor the RSMS to detect and measure characteristics of the various radio emitters that occupy the observed spectral band.

Data collection using the RSMS was accomplished at several different geographic locations. The first site was in Denver, CO, and for that testing, the measurements were performed during the week of August 29 through September 1, 1994 both at a public parking lot located at the intersection of 16th and Sherman Streets in downtown Denver, and from a site on Genesee Mountain overlooking, and about 16 kilometers west of, Denver. Data were also collected in the vicinity of Los Angeles, CA, specifically from an ITT Gilfillan antenna test range located at an old Nike anti-aircraft missile site on top of a mountain near Valencia, CA. The location afforded an almost unobstructed view of Los Angeles, including the Burbank, Van Nuys and Los Angeles International Airports, and many residential, business, and light industrial neighborhoods. In addition, the site had the advantage of having virtually no nearby 2400-2500 MHz emitters, with the possible exception of microwave ovens at a Fire Station located approximately 400 meters to the east.

Two basic types of data were collected during the testing, conventional spectrum analyzer sweeps across the frequency band of 2300-2600 MHz (Frequency Domain data), and Time Waveform "zero-span" sweeps at selected frequencies within that same frequency band. In each case a variety of analyzer bandwidths were utilized, and sufficient data were collected to allow for averaging and other types of statistical interpretation. The amount of data collected (about 500 megabytes) necessitated the use of data reduction techniques in order to provide a workable data set for analysis. In order to perform any data analysis however, the method of data collection must be well understood. For these tests the primary data collection devices were spectrum analyzers, so a brief discussion of the operation of those spectrum analyzers is warranted.

<u>The Spectrum Analyzer</u>

In simplest terms, the spectrum analyzers employed operate by tuning to a user-defined frequency and measuring the amount of energy present at that frequency in a user-defined measurement bandwidth. These measurements are performed such that 1001 points are recorded within any set of user-defined scan limits -- limits which could be, for example, start/stop frequencies for the frequency domain measurements, or start/stop times for time waveform measurements. The method utilized by the spectrum analyzer to determine the 1001-point recorded data is integral to any analysis of the potential impact of the sampled RF environment on other equipments.

The algorithms of interest -- *+peak* and *sample* modes -- are best explained through the use of an example. Suppose that the user requirement was that 20.02 milliseconds of time waveform data be collected on frequency 2450 MHz, with a measurement bandwidth of 300 kHz.

(20020 microseconds)÷(1001 recorded samples) = 20 microseconds per sample

The spectrum analyzers utilized in the measurement program incorporate analog detectors which determine the energy present in the selected measurement bandwidth. For *+peak mode*, the largest detected signal level during that 20 microsecond (μsec) period is used as the recorded sample. This results in a "worst case" snapshot of the time waveform. Conversely, in *sample mode*, the signal level registered on the detector at the end of the 20 μsec period is recorded. This methodology tends to present a more "averaged" view of the actual time waveform. Either or both of these characterizations of the RF environment could be of interest to an equipment manufacturer dependent on their particular design constraints.

For all tests, two spectrum analyzers were used simultaneously. This was accomplished such that direct comparisons could be made, either:

1. through the use of one analyzer as a "control" (ie. two measurements using different test setups and separated in time could be compared as each would have a companion data set collected under a standard set of bandwidth, detector type, etc. conditions), or,

2. in the omnidirectional versus directional antenna, by ensuring that both antennas were measuring the same environment.

Once the data were collected, post-test processing was performed to derive sets sufficiently small to be workable. For the Frequency Domain testing, the reduction scheme used was min/mean/max processing, while the Time Waveform measurements were reduced through the use of amplitude probability distributions (APDs).

The min/mean/max processing was as follows. For each tested IF bandwidth, approximately thirty, 10-second sweeps were performed. In each sweep, 1001 measurements, on 1001 frequencies equally spaced across the 2300-2600 MHz band, were stored. Recall, as outlined above, the stored value was either the maximum (for +Peak) or last (for Sample) sampled value depending on the sampling mode selected. When all of the sweeps were completed the data collection software reviewed the data and for each of the 1001 frequencies recorded the minimum, mean and maximum values of the thirty stored samples. Post-test processing software allowed like-data sets (e.g.. same IF bandwidth and sampling mode) to be further combined to construct min-of-mins, mean-of-means, and max-of-maxs curves.

For each IF bandwidth/center frequency combination, approximately 150,000 Time Waveform data samples were collected and stored. In order to analyze this pool of data, APDs were constructed to test the hypothesis that in the aggregate, the ISM signals combined so as to result in simply gaussian noise at a level elevated above that of purely thermal noise. Plotting samples from a gaussian distribution as the amplitude of the sample versus the percentage of samples which exceed that amplitude, results in the characteristic curve shown in Figure 1. If the APD of the aggregate ISM signals matched the shape of Figure 1, then the hypothesis would be supported.

RESULTS

Analyses of the data provided several interesting insights that should be useful to designers developing equipments for the 2400-2500 MHz ISM band. These observations are described below. As noted above, a considerable amount of data was collected during this effort. Though all of the data was examined, only a representative sample is reproduced in this report. Appendix A contains a complete listing of the tests performed.

a) General: Review of the data leads to several general observations. First, limited activity was noted in the frequency band from 2300 to 2400 MHz. This is not completely unexpected, as the band is allocated for amateur use and telemetry in flight testing of aircraft, spacecraft, and

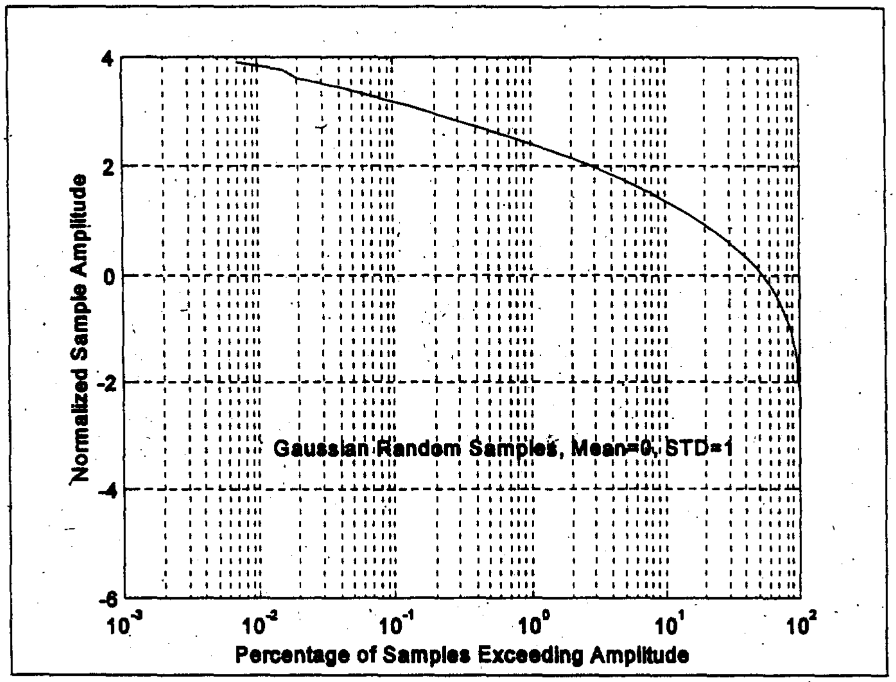

Figure 1: Amplitude Probability Distribution of a Sample of Gaussian-Distributed Random Amplitude Signals.